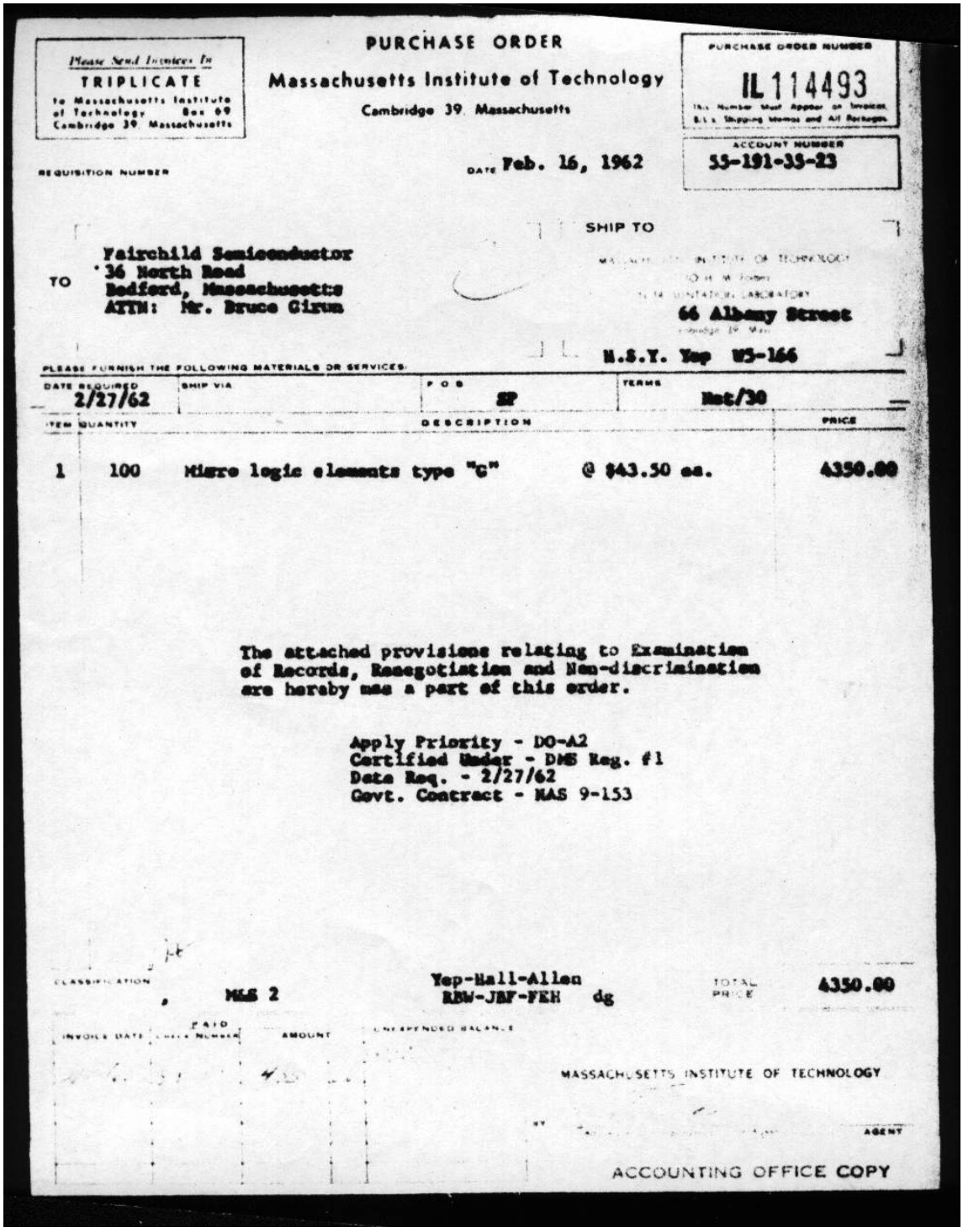
Integrated Circuits in the Apollo Guidance Computer

The decision, in 1962, to design the AGC using integrated circuit logic devices was critical to Apollo Computer's success and a key moment in the history of computing. Eldon Hall's *Journey to the Moon* recounts this decision process.

Following are copies of integrated circuit purchase orders for components required in the evaluation processes and the view graphs used to report the evaluation's conclusions to the NASA Program Office.

1. The evaluation process included procuring ICs from multiple vendors. Listed are copies of the most significant purchase orders placed by MIT/IL in 1962 and early 1963. These ICs were used to do extensive electrical evaluations which included building the computer pictured in Fig. 49 of *Journey to the Moon*. This work was under the direction of Dave Hanley as a parallel effort with the main line AGC design under the direction of Alonso and Hopkins using core-transistor logic.

2. The collection of view graphs summarizes the information presented to Mr. Charles W. Frick, NASA JSC Apollo Program Manager, in Nov. 1962. The presentation reported on the Lab's efforts to evaluate integrated circuits and the conclusions drawn concerning program impact of a proposed change in the AGC logic design from the core-transistor logic to integrated circuit logic. The requested change followed the presentation in a letter to the Mr. Frick from Dr Draper.



Please Send Invoices In
TRIPLICATE
to Massachusetts Institute of Technology Box 69
Cambridge 39 Massachusetts

PURCHASE ORDER

Massachusetts Institute of Technology
Cambridge 39 Massachusetts

PURCHASE ORDER NUMBER
IL 114493
This Number Must Appear on Invoices, B/L's Shipping Memos and All Packages

ACCOUNT NUMBER
55-191-35-23

REQUISITION NUMBER

DATE Feb. 16, 1962

SHIP TO

TO Fairchild Semiconductor
36 North Road
Bedford, Massachusetts
ATTN: Mr. Bruce Girun

66 Albany Street
N.S.Y. Yap W5-166

PLEASE FURNISH THE FOLLOWING MATERIALS OR SERVICES:

DATE REQUIRED	SHIP VIA	F O B	TERMS
2/27/62		SF	Net/30

ITEM	QUANTITY	DESCRIPTION		PRICE
1	100	Micro logic elements type "C"	@ $43.50 ea.	4350.00

The attached provisions relating to Examination of Records, Renegotiation and Non-discrimination are hereby made a part of this order.

Apply Priority - DO-A2
Certified Under - DMS Reg. #1
Date Req. - 2/27/62
Govt. Contract - NAS 9-153

CLASSIFICATION MAS 2

Yep-Hall-Allen
RBW-JBF-FEH dg

TOTAL PRICE 4350.00

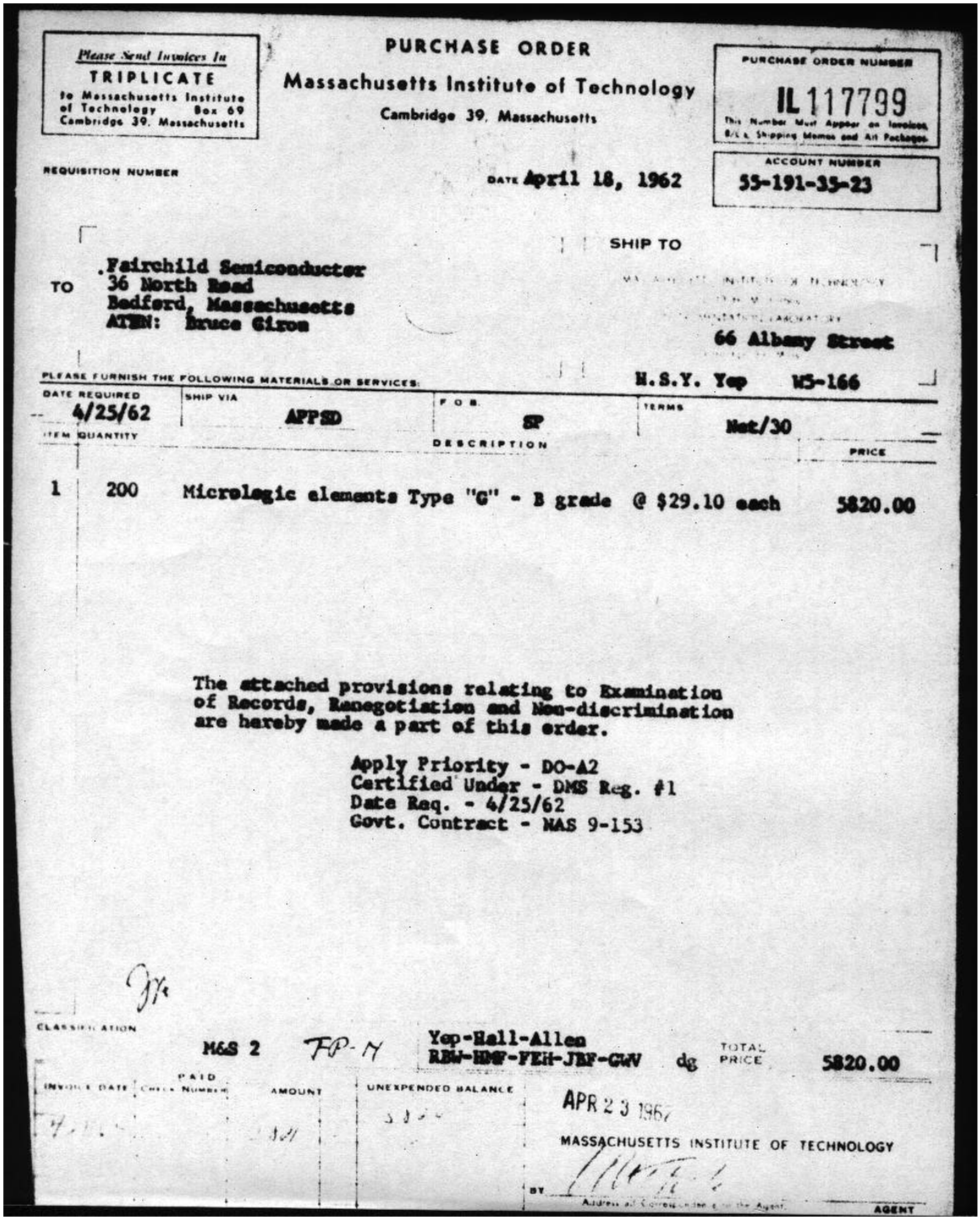
INVOICE DATE	PAID CHECK NUMBER	AMOUNT	UNEXPENDED BALANCE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

BY AGENT

ACCOUNTING OFFICE COPY

This is the first integrated circuit purchase order for the Apollo Program by MIT/IL. Delivery was just a few days.
There were a few earlier orders including the first by MIT/IL to Texas Instruments in 1959 for 64 ICs at $1000 each. That TI order was not delivered until late 1962.



Please Send Invoices In
TRIPLICATE
to Massachusetts Institute of Technology Box 69
Cambridge 39, Massachusetts

PURCHASE ORDER

Massachusetts Institute of Technology
Cambridge 39, Massachusetts

PURCHASE ORDER NUMBER
IL 117799
This Number Must Appear on Invoices, B/L's, Shipping Memos and All Packages

REQUISITION NUMBER

DATE April 18, 1962

ACCOUNT NUMBER
55-191-35-23

SHIP TO
66 Albany Street

TO .Fairchild Semiconducter
36 North Road
Bedford, Massachusetts
ATTN: Bruce Giroa

PLEASE FURNISH THE FOLLOWING MATERIALS OR SERVICES:

N.S.Y. Yep W5-166

DATE REQUIRED	SHIP VIA	F.O.B.	TERMS
4/25/62	APPSD	SP	Net/30

ITEM	QUANTITY	DESCRIPTION	PRICE
1	200	Microlegic elements Type "G" - B grade @ $29.10 each	5820.00

The attached provisions relating to Examination of Records, Renegotiation and Non-discrimination are hereby made a part of this order.

Apply Priority - DO-A2
Certified Under - DMS Reg. #1
Date Req. - 4/25/62
Govt. Contract - NAS 9-153

CLASSIFICATION M&S 2 FP-N

Yep-Hall-Allen
RBW-HMF-FEH-JBF-GWV dg

TOTAL PRICE 5820.00

INVOICE DATE	PAID CHECK NUMBER	AMOUNT	UNEXPENDED BALANCE
7-1-62	141		5820

APR 23 1962

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

BY

Address all Correspondence to the Agent

AGENT

The third order placed with Fairchild. All were delivered in just a few days. It was apparent that Fairchild had these quantities in stock.

Please Send Invoices In
TRIPLICATE
to Massachusetts Institute of Technology Box 69
Cambridge 39, Massachusetts

PURCHASE ORDER

Massachusetts Institute of Technology
Cambridge 39, Massachusetts

PAGE 1 of 2

PURCHASE ORDER NUMBER
IL120534
This Number Must Appear on Invoices, Bills, Shipping Memos and Air Packages

ACCOUNT NUMBER
55-191-37-23

REQUISITION NUMBER

DATE May 28, 1962

SHIP TO

TO Fairchild Semi-Conductor Corp.
36 North Road
Bedford, Massachusetts
ATTN: Mr. Bruce Giron

68 Albany Street

E.J. Duggan W5-151

PLEASE FURNISH THE FOLLOWING MATERIALS OR SERVICES:

DATE REQUIRED	SHIP VIA	F O B	TERMS
SEE BELOW	AMSD	SP	Net/30

ITEM	QUANTITY	DESCRIPTION	PRICE
1	1000	pieces "B" Grade Gate Element in TO47 package, Fairchild P/N SL 1015 per MIT print C-88794 change B, @ $31.10 each	31100.00

1. To conform with MIT requirements, Fairchild P/N 1015 will have lead orientation in accordance with C-88794-B as agreed upon by Mr. E. Duggan of MIT, and R. Graham, M. Siegel, and B. Giron of Fairchild on May 15, 1962.

   A. Leads 2 and 6 will be clipped off by Fairchild prior to shipment.

   B. As soon as appropriate headers are available, Leads 2 and 6 will be eliminated from the header. The resulting header then will be identical to the standard TO47 Flip-Flop pkg.

Shipment of 100 pieces will be made 30 days after receipt of order. When TO47 headers are available, the balance will be shipped at a rate of 150 pieces per week, beginning no later than July 15, 1962.

CLASSIFICATION M&S 2 FP-Y

Duggan-Hall-Trageser-Allen RHT-HDG-FEH-JBF dg

TOTAL PRICE

SEE PAGE 2

INVOICE DATE	PAID CHECK NUMBER	AMOUNT	UNEXPENDED BALANCE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

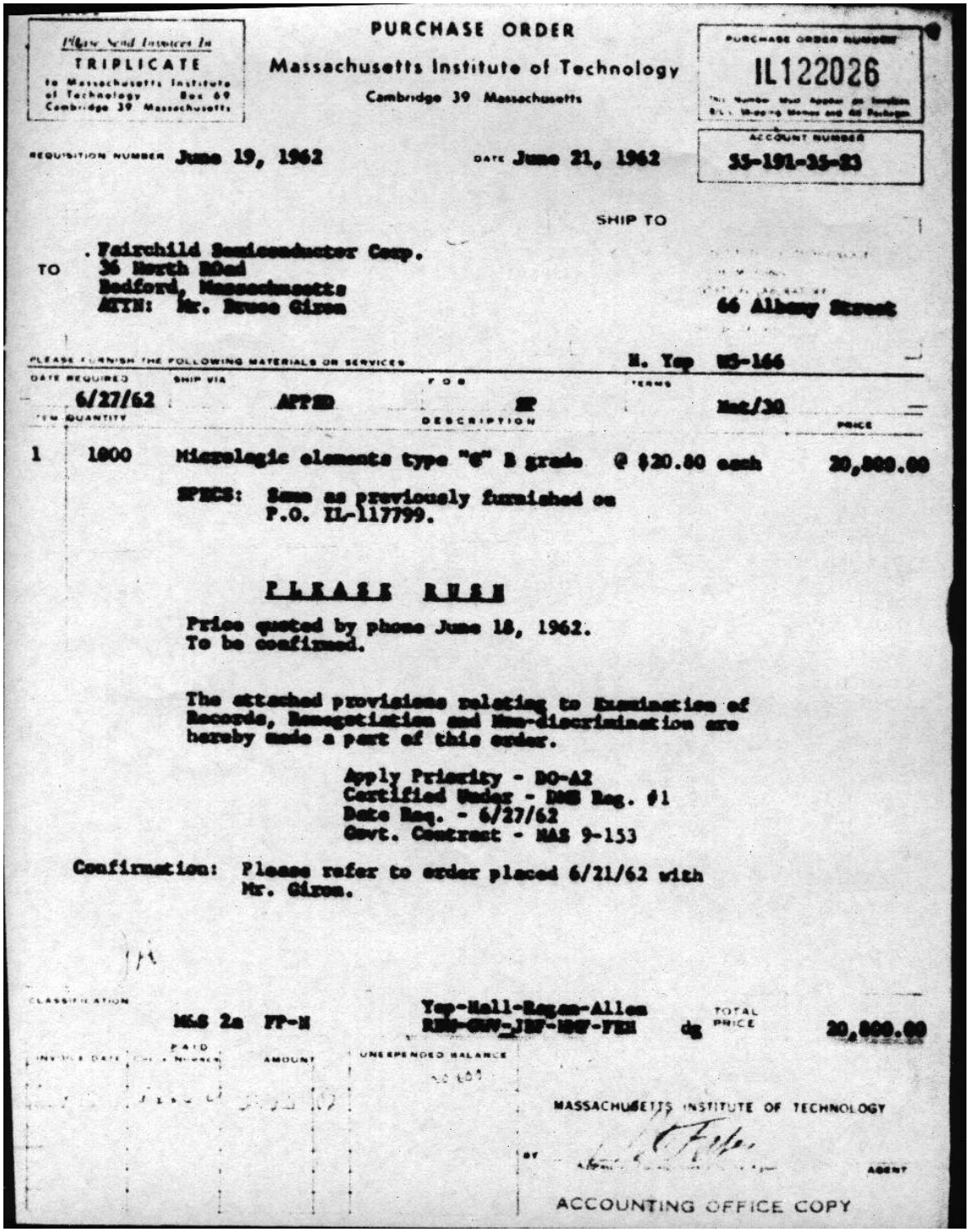
BY

AGENT

ACCOUNTING OFFICE COPY

TRIPLICATE Massachusetts Institute of Technology IL 120534
Cambridge 39 Massachusetts

The previous orders were for Fairchild's commercial grade devices. Apollo production procurements would require a detailed specification. In this order the mechanical configuration of the gate element is specified and the electrical characteristics remain the same as the commercial grade device. Deliveries were on schedule.



PURCHASE ORDER

Massachusetts Institute of Technology

Cambridge 39 Massachusetts

Please Send Invoices In TRIPLICATE to Massachusetts Institute of Technology Box 69 Cambridge 39 Massachusetts

PURCHASE ORDER NUMBER IL122026

REQUISITION NUMBER June 19, 1962

DATE June 21, 1962

ACCOUNT NUMBER 55-191-35-83

SHIP TO

TO . Fairchild Semiconductor Corp.
36 North Road
Bedford, Massachusetts
ATTN: Mr. Bruce Girsn

66 Albany Street

PLEASE FURNISH THE FOLLOWING MATERIALS OR SERVICES

N. Yep 55-166

DATE REQUIRED	SHIP VIA	F O B	TERMS
6/27/62	APTD	NF	Net/30

ITEM	QUANTITY	DESCRIPTION	PRICE	
1	1000	Micrologic elements type "G" B grade	@ $20.00 each	20,000.00

SPECS: Same as previously furnished on P.O. IL-117799.

PLEASE RUSH

Price quoted by phone June 18, 1962.
To be confirmed.

The attached provisions relating to Examination of Records, Renegotiation and Non-discrimination are hereby made a part of this order.

Apply Priority - DO-A2
Certified Under - DMS Reg. #1
Date Req. - 6/27/62
Govt. Contract - NAS 9-153

Confirmation: Please refer to order placed 6/21/62 with Mr. Girsn.

CLASSIFICATION M&S 2a FP-H

Yep-Hall-Regan-Allen RHR-GHV-JHF-HMF-FEH dg

TOTAL PRICE 20,000.00

INVOICE DATE	PAID VOUCHER NUMBER	AMOUNT	UNEXPENDED BALANCE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

BY [signature] AGENT

ACCOUNTING OFFICE COPY

At this point in time larger quantities were needed to continue design and construction of the IC version Apollo Guidance Computer. As required, delivery time was just a few days.

Please Send Invoices In
TRIPLICATE
to Massachusetts Institute of Technology Box 69 Cambridge 39, Massachusetts

PURCHASE ORDER

Massachusetts Institute of Technology

Cambridge 39, Massachusetts

PURCHASE ORDER NUMBER
IL 128895
This Number Must Appear on Invoices, B/L's, Shipping Memos and All Packages

REQUISITION NUMBER Oct. 25, 1962

DATE Oct. 30, 1962

ACCOUNT NUMBER
55-181-35-23

TO Fairchild Semiconductor
36 North Road
Bedford, Massachusetts
ATTN: Bruce Giron

SHIP TO
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
c/o H. M. Forbes
INSTRUMENTATION LABORATORY
66 Albany Street
Cambridge 39, Mass

PLEASE FURNISH THE FOLLOWING MATERIALS OR SERVICES: N. Yap 95-166

DATE REQUIRED	SHIP VIA	F. O. B.	TERMS
11/2/62	APPD	DF	Net/30

ITEM	QUANTITY	DESCRIPTION	PRICE
1	1500	Micrologic elements type "G" "B" grade @ $11.25 each	16,875.00

SPECS: Same as previously furnished on P.O. IL 124738.

PLEASE RUSH

PRICE CERTIFICATION:

Seller certifies that prices appearing on Fairchild Micrologic Pricing dated September 13, 1962, for the effective time period of this schedule are not in excess of those charged any other customer for like items in similar quantities under similar conditions. The references to any other customer refers to agencies of the United States Government and commercial customers.

The attached provisions relating to Examination of Records, Renegotiation and Non-discrimination are hereby made a part of this order.

Apply Priority - DO-A2
Certified Under - DMS Reg. #1
Date Req. - 11/2/62
Govt. Contract - NAS 9-153

NOTE: Prepay shipping charges and add to invoice.

CLASSIFICATION MSS 2a FP-H

Yap-Hall-Allen

TOTAL PRICE 16,875.00

INVOICE DATE	CHECK NUMBER	AMOUNT PAID	UNEXPENDED BALANCE
11/5/62	R.S.062	[illegible]	168.75
11/16/62	R 10 CL 6753	as	

Dec. 31, 1962

NOV 1962 IL 128895

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

ACCOUNTING OFFICE COPY

SHIP TO

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Note: On time delivery and a significant price reduction.

Please Send Invoices In TRIPLICATE to Massachusetts Institute of Technology Box 69 Cambridge 39 Massachusetts

Massachusetts Institute of Technology
Cambridge 39 Massachusetts

IL 127194
This Number Must Appear on Invoices, Bills, Shipping Memos and All Packages

REQUISITION NUMBER **Sept. 17, 1962** DATE **Sept. 20, 1962**

ACCOUNT NUMBER **55-191-35-23**

SHIP TO

TO **Texas Instruments Inc.**
31 Washington Street
Wellesley Hill, Massachusetts

66 Albany Street

PLEASE FURNISH THE FOLLOWING MATERIALS OR SERVICES: **H. Yep W5-166**

DATE REQUIRED	SHIP VIA	F O B	TERMS
10/30/62	APPSD	SF	Net/30

ITEM	QUANTITY	DESCRIPTION	PRICE
1	100	Micro logic elements - Modified 53 series logic gate Pt. #SM308 @ $40.00 each	4,000.00

SPECS:

1. 25 n. sec. propagation delay.
2. 3v supply, 15 - 20 mw or less.
3. Mech. same as per NASA dwg. #1006771.
4. Elect. specs: as per conference in MIT Instrumentation Lab. on Sept. 11, 1962, between Mr. J. S. Kilby of T.I. and Mr. D. Hanley of MIT.
5. Firm delivery 6 to 8 weeks.
6. Drawing #1006771 attached.

URGENT PLEASE RUSH

This order is based on your quotation dated Sept. 12, 1962, signed D. F. McGuinness.

The attached provisions relating to Examination of Records, Renegotiation and Non-discrimination are hereby made a part of this order.

Apply Priority - DO-A2
Certified Under - DMS Reg. #1
Date Req. - 10/30/62
Govt. Contract - NAS 9-153
Yep-Hall-Allen
REM-GNV-JBF-FEH dg

CLASSIFICATION M&S FP-N

TOTAL PRICE 4,000.00

PAID CHK. NUMBER AMOUNT UNEXPENDED BALANCE

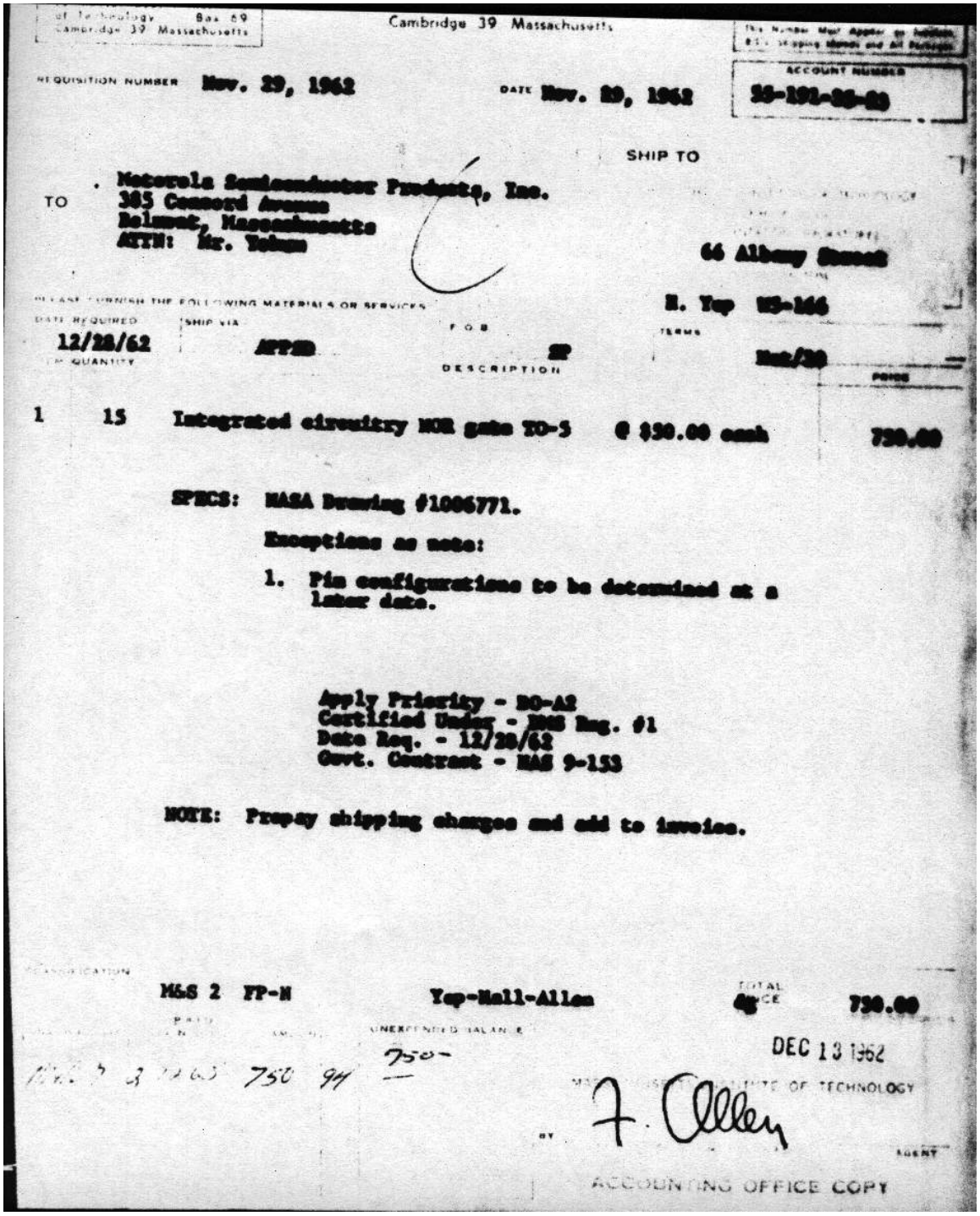
P 25 1962

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

BY _____ AGENT

ACCOUNTING OFFICE COPY

Development of additional sources of supply started early in 1962. Above is the PO for the first significant order from an alternate source. Devices were delivered late.



Cambridge 39 Massachusetts

REQUISITION NUMBER Nov. 29, 1962 DATE Nov. 29, 1962

ACCOUNT NUMBER 18-191-88-88

SHIP TO

TO Motorola Semiconductor Products, Inc.
385 Concord Avenue
Belmont, Massachusetts
ATTN: Mr. Tobias

66 Albany Street

E. Yep 85-166

PLEASE FURNISH THE FOLLOWING MATERIALS OR SERVICES

DATE REQUIRED 12/28/62 SHIP VIA AFTR F.O.B. DESTINATION TERMS Net/30

QUANTITY		DESCRIPTION	PRICE
1	15	Integrated circuitry NOR gate TO-5 @ $50.00 each	750.00

SPECS: NASA Drawing #1006771.

Exceptions as noted:

1. Pin configurations to be determined at a later date.

Apply Priority - DO-A2
Certified Under - DMS Reg. #1
Date Req. - 12/28/62
Govt. Contract - NAS 9-153

NOTE: Prepay shipping charges and add to invoice.

M&S 2 FP-N Yep-Hall-Allen TOTAL PRICE 750.00

UNEXPENDED BALANCE

750-

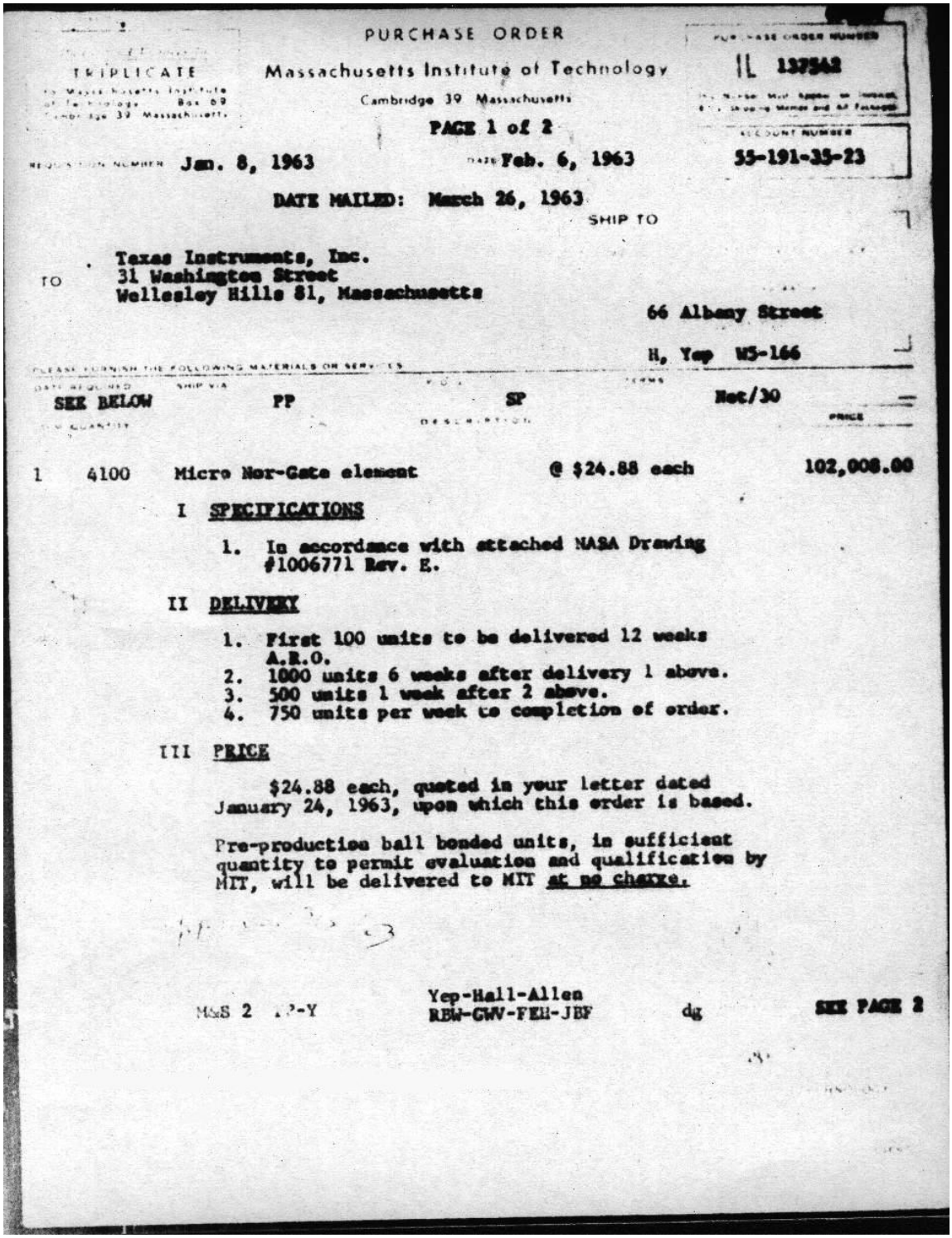
DEC 13 1962

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

BY J. Allen AGENT

ACCOUNTING OFFICE COPY

Motorola delivered late and did not develop into a satisfactory source of supply.



PURCHASE ORDER

TRIPLICATE

Massachusetts Institute of Technology

Cambridge 39 Massachusetts

PAGE 1 of 2

PURCHASE ORDER NUMBER IL 127562

REQUISITION NUMBER Jan. 8, 1963

DATE Feb. 6, 1963

ACCOUNT NUMBER 55-191-35-23

DATE MAILED: March 26, 1963

SHIP TO

TO Texas Instruments, Inc.
31 Washington Street
Wellesley Hills 81, Massachusetts

66 Albany Street

H, Yep W5-166

PLEASE FURNISH THE FOLLOWING MATERIALS OR SERVICES

DATE REQUIRED	SHIP VIA	F.O.B.	TERMS
SEE BELOW	PP	SP	Net/30

QUANTITY	DESCRIPTION	PRICE
1 4100	Micro Nor-Gate element @ $24.88 each	102,008.00

I SPECIFICATIONS

1. In accordance with attached NASA Drawing #1006771 Rev. E.

II DELIVERY

1. First 100 units to be delivered 12 weeks A.R.O.
2. 1000 units 6 weeks after delivery 1 above.
3. 500 units 1 week after 2 above.
4. 750 units per week to completion of order.

III PRICE

$24.88 each, quoted in your letter dated January 24, 1963, upon which this order is based.

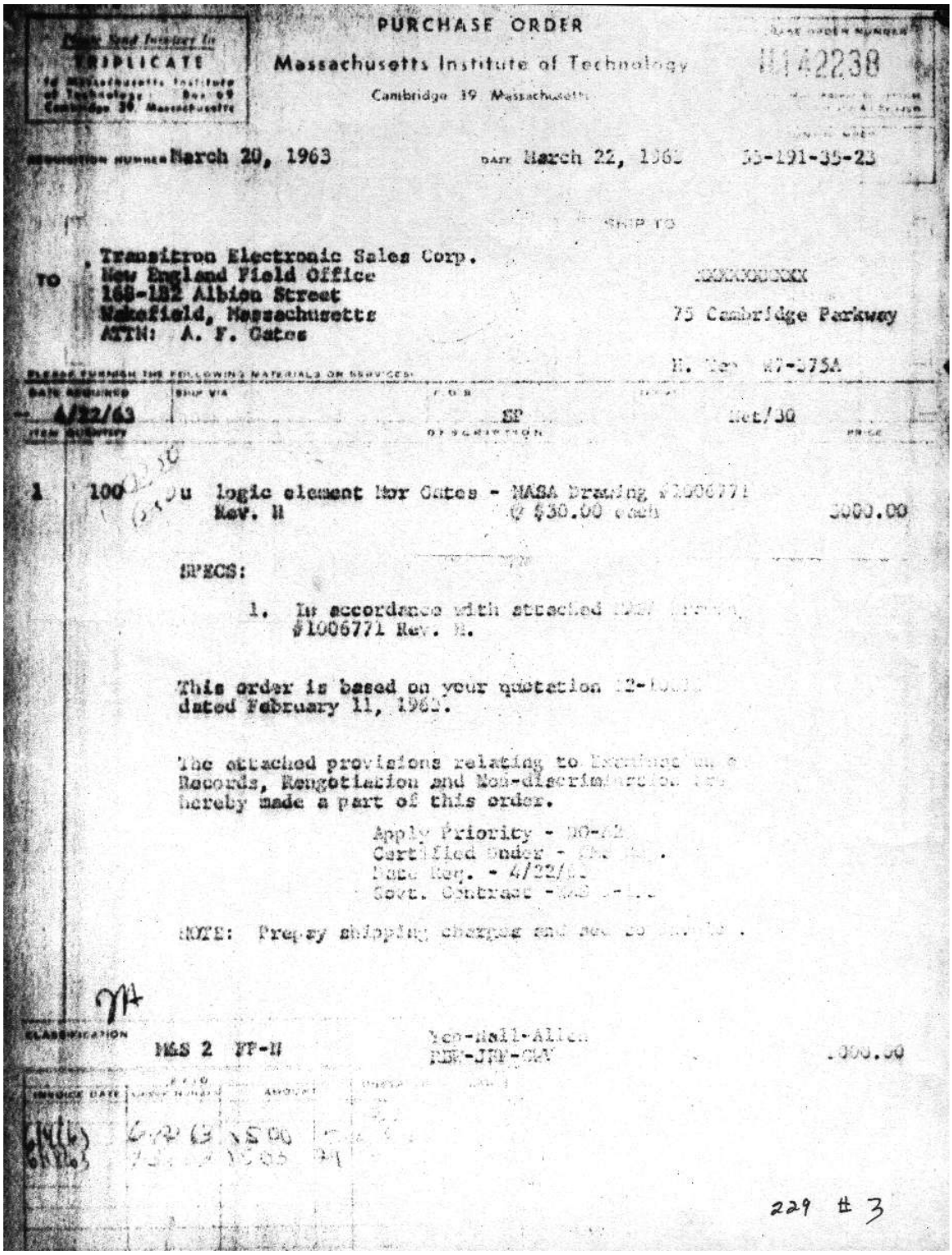
Pre-production ball bonded units, in sufficient quantity to permit evaluation and qualification by MIT, will be delivered to MIT at no charge.

M&S 2 ..?-Y

Yep-Hall-Allen
RBW-GWV-FEH-JBF dg

SEE PAGE 2

Based upon the satisfactory evaluation of the devices delivered per Purchase Order placed in Sept 1962, # IL 127194 above, this order was placed. The order was canceled in Nov. 1963 for failure to deliver.
Texas Instruments continued working on the project and became a significant source of supply in about one year.



PURCHASE ORDER

TRIPLICATE

Massachusetts Institute of Technology

Cambridge 39 Massachusetts

H142238

March 20, 1963 — March 22, 1963 — 35-191-35-23

SHIP TO

TO: Transitron Electronic Sales Corp.
New England Field Office
168-182 Albion Street
Wakefield, Massachusetts
ATTN: A. F. Gates

75 Cambridge Parkway

DATE REQUIRED: 4/22/63 — SHIP VIA — F.O.B. — TERMS: Net/30

ITEM NO.	QUANTITY	DESCRIPTION	PRICE
1	100	u logic element Nor Gates - NASA Drawing #1006771 Rev. H @ $30.00 each	3000.00

SPECS:

1. In accordance with attached [illegible] #1006771 Rev. H.

This order is based on your quotation [illegible] dated February 11, 1963.

The attached provisions relating to [illegible] Records, Renegotiation and Non-discrimination [illegible] hereby made a part of this order.

Apply Priority - DO-A2
Certified Under - [illegible]
Date Req. - 4/22/63
Govt. Contract - [illegible]

NOTE: Prepay shipping charges and [illegible]

CLASSIFICATION: MGS 2 FT-H — Non-Mail-Allow. PER-JTW-CAV — .000.00

INVOICE DATE — AMOUNT — 6-26-63 — 3000

229 # 3

The first order to Transitron resulted in satisfactory devices delivered on time.

TRIPLICATE

PURCHASE ORDER

Massachusetts Institute of Technology
Cambridge 39 Massachusetts

PURCHASE ORDER NUMBER 1143076

DATE MAILED: April 11, 1963

REQUISITION NUMBER March 26, 1963 DATE April 1, 1963

ACCOUNT NUMBER 55-191-35-23

SHIP TO

TO Fairchild Semiconductor Corporation
35 North Road
Bedford, Massachusetts
ATTN: Mr. Bruce Girvan

XXXXXXXXX
75 Cambridge Parkway

PLEASE FURNISH THE FOLLOWING MATERIALS OR SERVICES

H. Yep W7-375A

DATE REQUIRED	SHIP VIA	F.O.B.	TERMS
SEE BELOW	AMED	Mt. View, Calif.	Net/30

ITEM	QUANTITY	DESCRIPTION	PRICE
1	3000	μ logic elements, Nor gate - NASA Drawing #1006771 Rev. H in TO-5 package @ $15.00 each	45,000.00

SPECS: 1. Attached NASA Drawing #1006771 Rev. H.
2. Exception: - size TO-5.
3. DELIVERY:
1000 units - May 3, 1963.
Balance - on or before 6/3/63.

This order is based on your quotation [illegible].

PRICE CERTIFICATION:

Seller certifies that prices appearing in this quote are not in excess of those charged to any other customer for like items in similar quantities under similar conditions. The reference to any other customers refers to agencies of the United States Government and commercial customers.

The attached provisions relating to Termination of Records, Renegotiation and Non-discrimination are hereby made a part of this order.

Apply Priority - [illegible]
Certified Order - [illegible]
Date Req. - [illegible]
Govt. Contract - [illegible]

NOTE: Prepay shipping charges and add to [illegible].

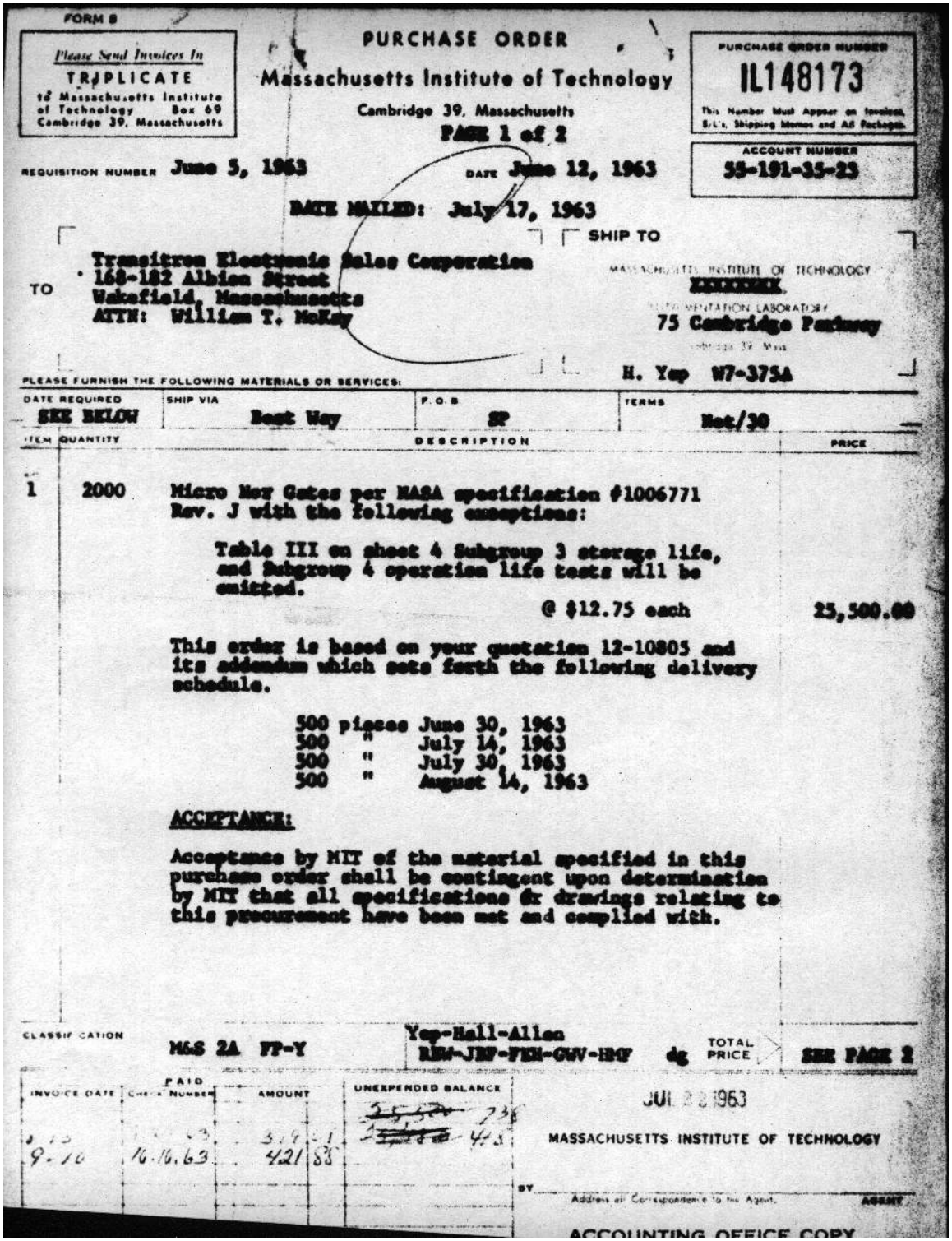
CLASSIFICATION M&S 2 FP-Y

Yep-Hall-Bryant-Allen
RBH-GLW-JHT-FWH

45,000.00

APR 15 1963

PAID			
INVOICE DATE	CHECK NUMBER	AMOUNT	UNEXPENDED BALANCE
5/24	C15163	15,000	93
6/13	C15543	15,000	93
7/31	C15724	13,669	24



FORM 8

Please Send Invoices In TRIPLICATE to Massachusetts Institute of Technology Box 69 Cambridge 39, Massachusetts

PURCHASE ORDER

Massachusetts Institute of Technology
Cambridge 39, Massachusetts
PAGE 1 of 2

PURCHASE ORDER NUMBER IL148173
This Number Must Appear on Invoices, B/L's, Shipping Memos and All Packages

ACCOUNT NUMBER 55-191-35-23

REQUISITION NUMBER June 5, 1963 DATE June 12, 1963

DATE MAILED: July 17, 1963

TO Transitron Electronic Sales Corporation
168-182 Albion Street
Wakefield, Massachusetts
ATTN: William T. McKay

SHIP TO MASSACHUSETTS INSTITUTE OF TECHNOLOGY
INSTRUMENTATION LABORATORY
75 Cambridge Parkway
H. Yap W7-375A

PLEASE FURNISH THE FOLLOWING MATERIALS OR SERVICES:

DATE REQUIRED	SHIP VIA	F.O.B.	TERMS
SEE BELOW	Best Way	SP	Net/30

ITEM	QUANTITY	DESCRIPTION	PRICE
1	2000	Micro Mor Gates per NASA specification #1006771 Rev. J with the following exceptions:	
		Table III on sheet 4 Subgroup 3 storage life, and Subgroup 4 operation life tests will be omitted.	
		@ $12.75 each	25,500.00

This order is based on your quotation 12-10805 and its addendum which sets forth the following delivery schedule.

500 pieces June 30, 1963
500 " July 14, 1963
500 " July 30, 1963
500 " August 14, 1963

ACCEPTANCE:

Acceptance by MIT of the material specified in this purchase order shall be contingent upon determination by MIT that all specifications & drawings relating to this procurement have been met and complied with.

CLASSIFICATION M&S 2A FP-Y

Yap-Hall-Allen
REH-JHF-FEH-GWV-HMF dg

TOTAL PRICE SEE PAGE 2

INVOICE DATE	PAID CHECK NUMBER	AMOUNT	UNEXPENDED BALANCE
9-10	16.16.63	421 88	

JUL 2 8 1963

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

BY Address all Correspondence to the Agent. AGENT

ACCOUNTING OFFICE COPY

Transitron became the first alternate source that delivered significant quantities on time. Also note, the specification # 1006771 included quality control requirements that were waivered for these devices. Fast delivery was a priority at this time.

142237

March 19, 1963 March 22, 1963 55-191-35-23

Westinghouse Electric Corporation
[illegible]
[illegible], Massachusetts
ATTN: Mr. J. C. Bailey

XXXXXXXX
75 Cambridge Parkway

H. Yep U7-375A

4/20/63 SP Net/30

125 μ logic element Nor Gate NASA Drawing #1006771 Rev. H
@ $77.60 each 9700.00

SPECS: 1. In accordance with attached NASA Drawing #1006771 Rev. H.

2. Mechanical: these units will be in TO-5 headers, pin connection-bases 1, 2, & 3 collector resistor pin 8, emitters pin 4 output pin 6.

This order is based on your letter quotation dated March 1, 1963, signed Joseph C. Bailey.

The attached provisions relating to Examination of Records, Renegotiation and Non-discrimination are hereby made a part of this order.

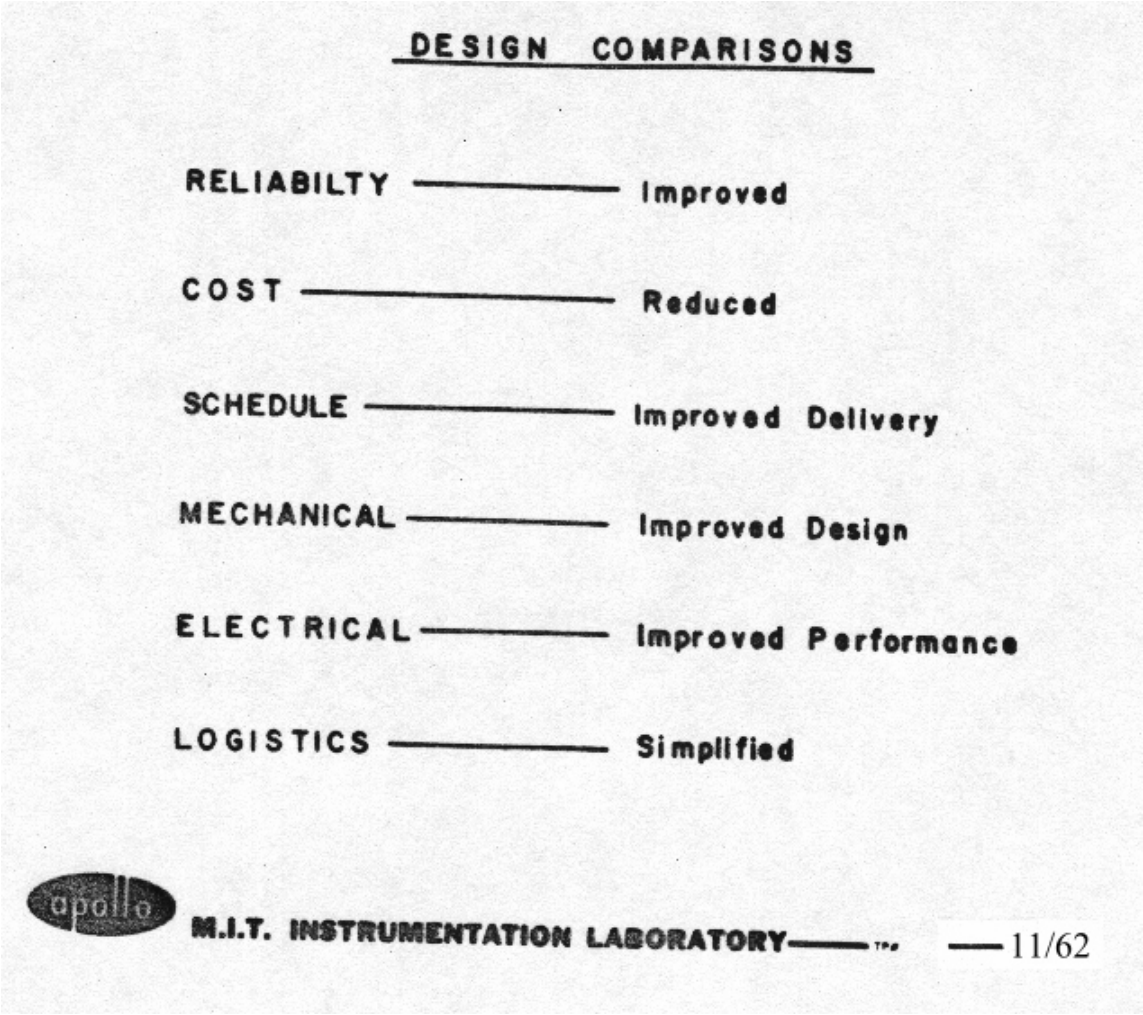
Apply Priority - DO-A2
Certified Under - DMS Reg. [illegible]
Date Req. - 4/20/63
Govt. Contract - NAS 9-150

NOTE: Prepay shipping charges and add to invoice.

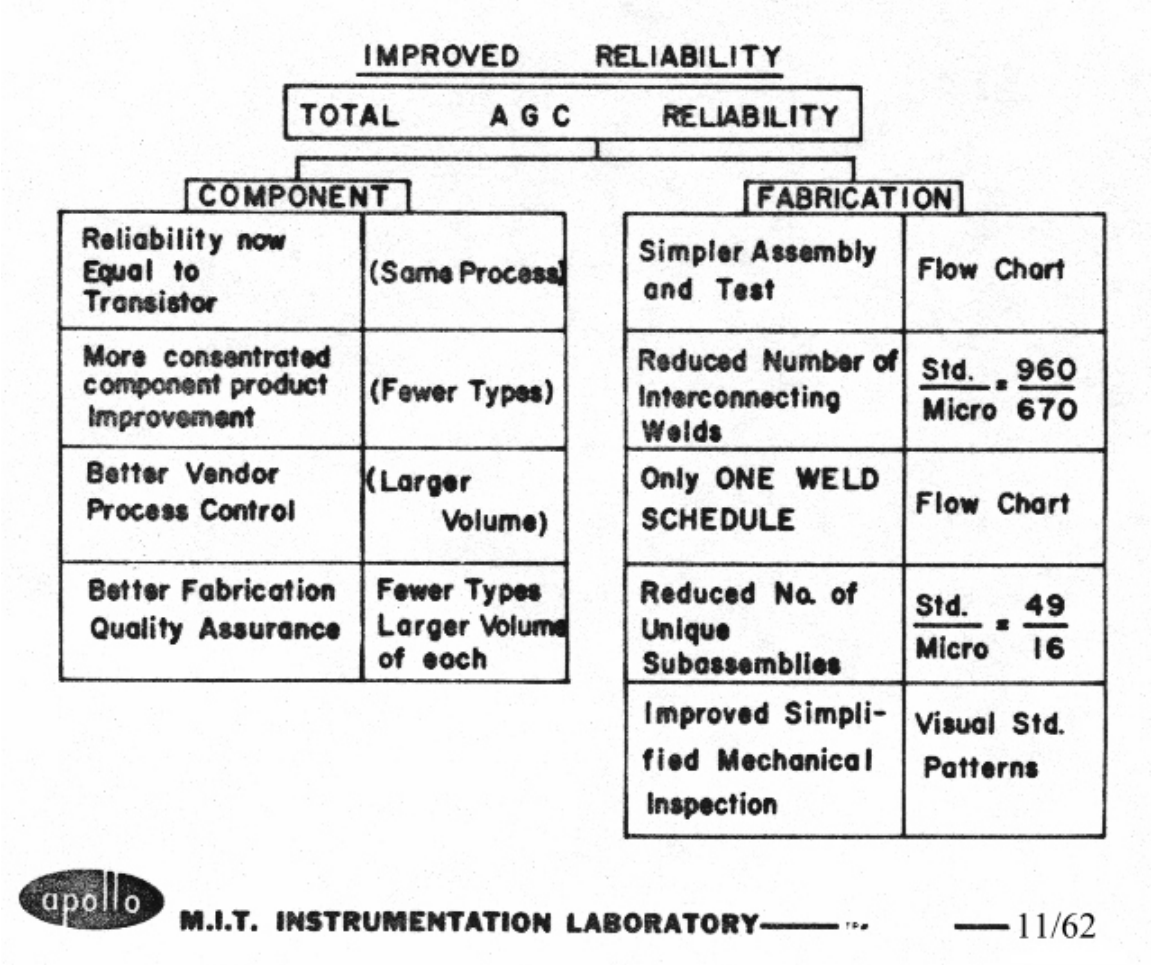
NAS 2 FP-N Yep-Hall-Allen RBW-GWV-JBF-FLH 9700.00

229 #3

In November 1962 the MIT/IL prepared the following view graphs for a presentation to Charles W. Frick, NASA JSC Apollo Program Manager. The presentation was a report on the Lab's efforts to evaluate integrated circuits and the program impact of a proposed change in the AGC logic design from the core-transistor logic to integrated circuit logic.



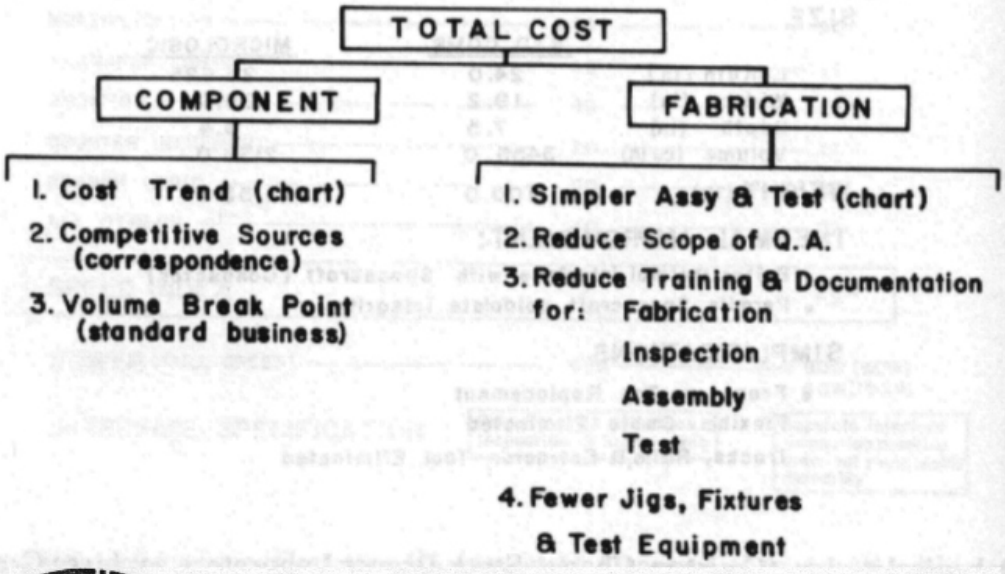
This first view graph lists the conclusions of the effort. The following view graphs expands on each point.

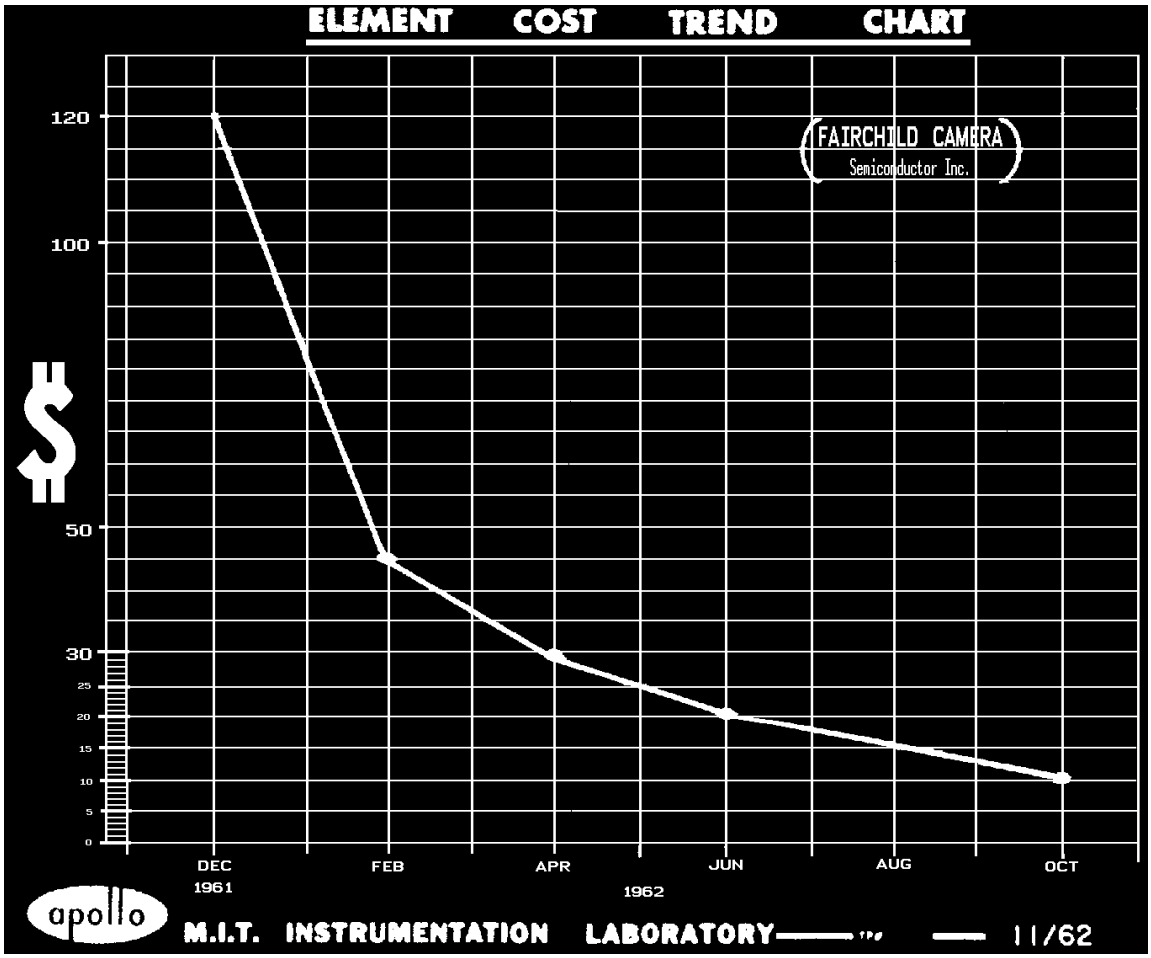


Reliability was a major issue for the Apollo Guidance Computer and all aspects were considered in the evaluation of the proposed integrated circuit design change. Standardization on the single logic component would realize many advantages during the computer's assembly and test as indicated in this view graph. Standardization would also provide benefits for the semiconductor industry but, the study could not evaluate many of the potential risks associated with such an immature semiconductor component. An intensified effort would be necessary to provide the necessary assurance that integrated circuits would realize the reliability required for the Apollo application.

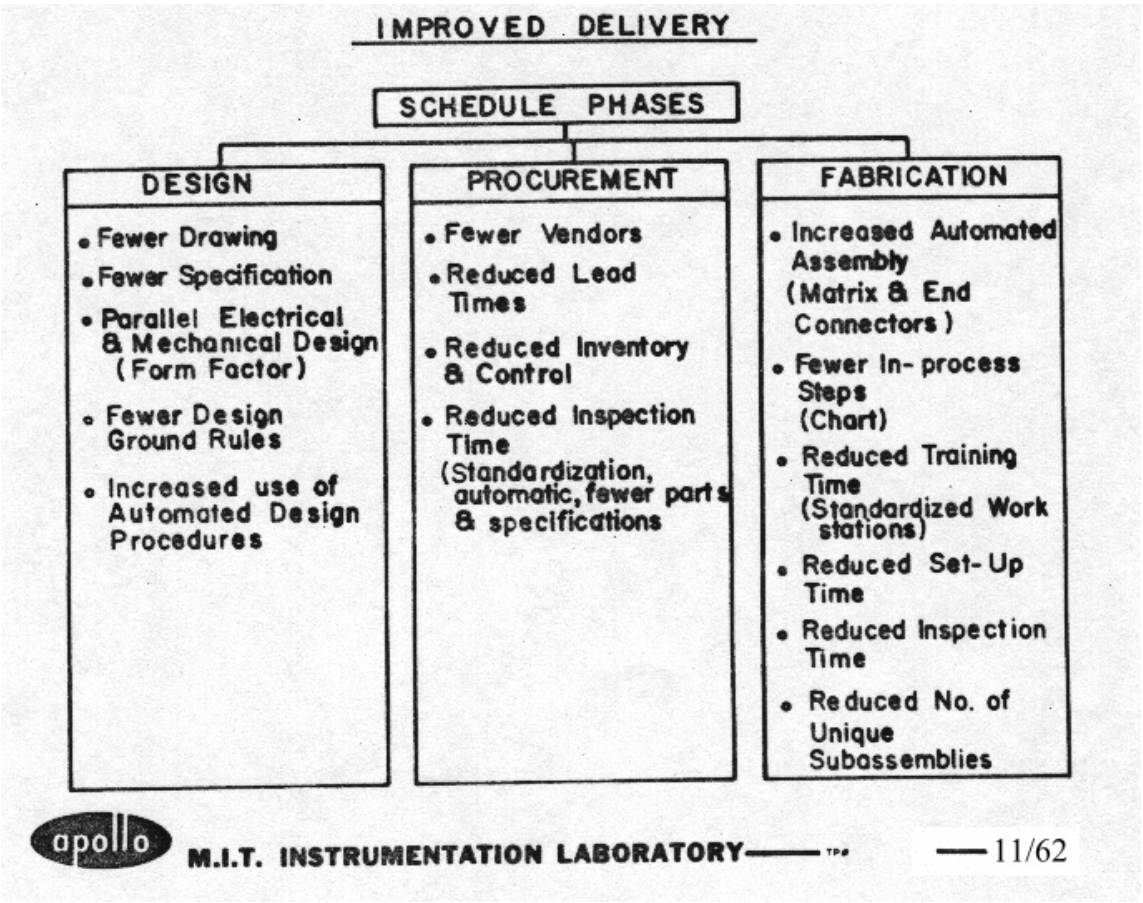
Maintaining a source of supply of quality integrated circuits could be difficult over the production life of the Apollo Computer. The semiconductor industry was dedicated to advancing the "state of the art" and to accomplish this goal it was plagued with process changes, inadvertent and intentional. Such changes contributed to uncertainties in a semiconductor product's functional stability, quality, reliability and production life. Considering the critical reliability and production life time requirements of the AGC in the Apollo System, an approach to IC procurement had to be developed which would insure a supply of quality components.

REDUCED COST





This view graph portrays the IC cost reduction realized during the evaluation procurements.



Integrated circuits introduced major technology improvements in the methods to interconnect electronic components and reduced the labor required during fabrication. Electronic components in an IC are interconnected automatically on the surface of the semiconductor chip. Interconnecting the large numbers of individual electronic components in conventional computer logic circuits such as the core-transistor logic planned for the AGC was labor intensive.

Next multilayer printed circuit boards which were invented in 1959, became commercially available in the early 1960s. Printed boards would allow the interconnections between ICs to be automated. To maximize the advantages of printed board technology, ICs had to be packaged in a flat pack configuration versus the multileaded transistor type package (TO-47) that Fairchild supplied to MIT in the previous orders. This improvement became available when Fairchild introduced a dual NOR gate in a flat pack configuration in 1963. The dual gate and multilayer printed boards became available just in time for the second generation AGC which would be required for the Lunar Landing Module.

IMPROVED MECHANICAL DESIGN

SIZE

	STD. COMP.	MICROLOGIC
Length (in)	24.0	25.625
Width (in)	19.2	20.0
Depth (in)	7.5	4.4
Volume (cu in)	3456.0	2136.0
WEIGHT (lb)	100.0	58.0

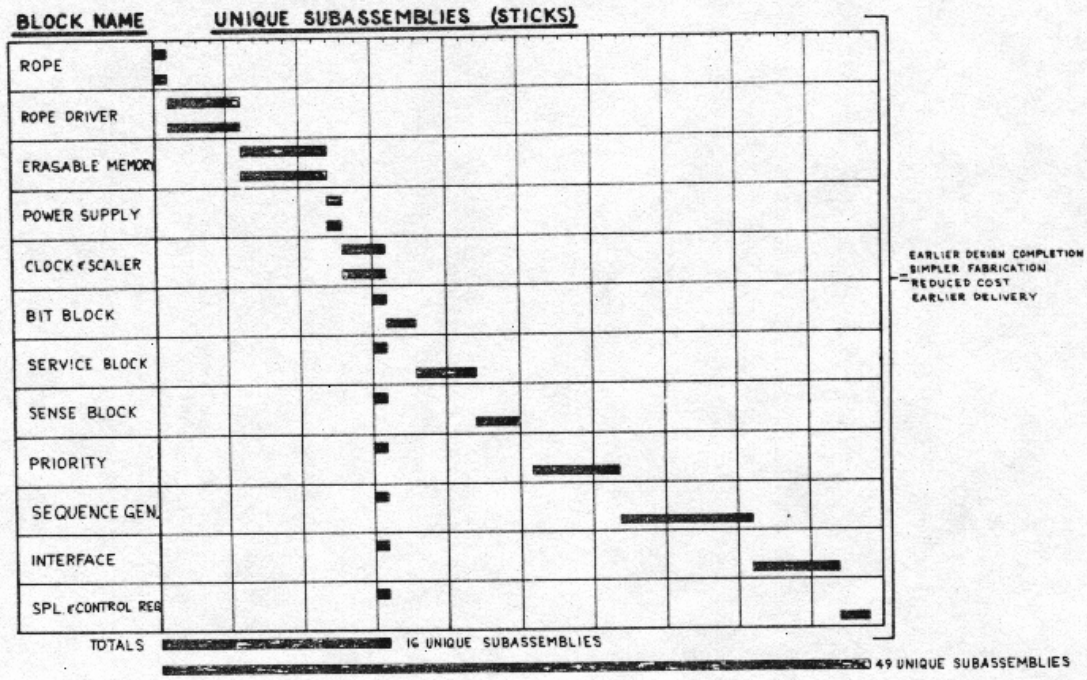
THERMAL IMPROVEMENT:

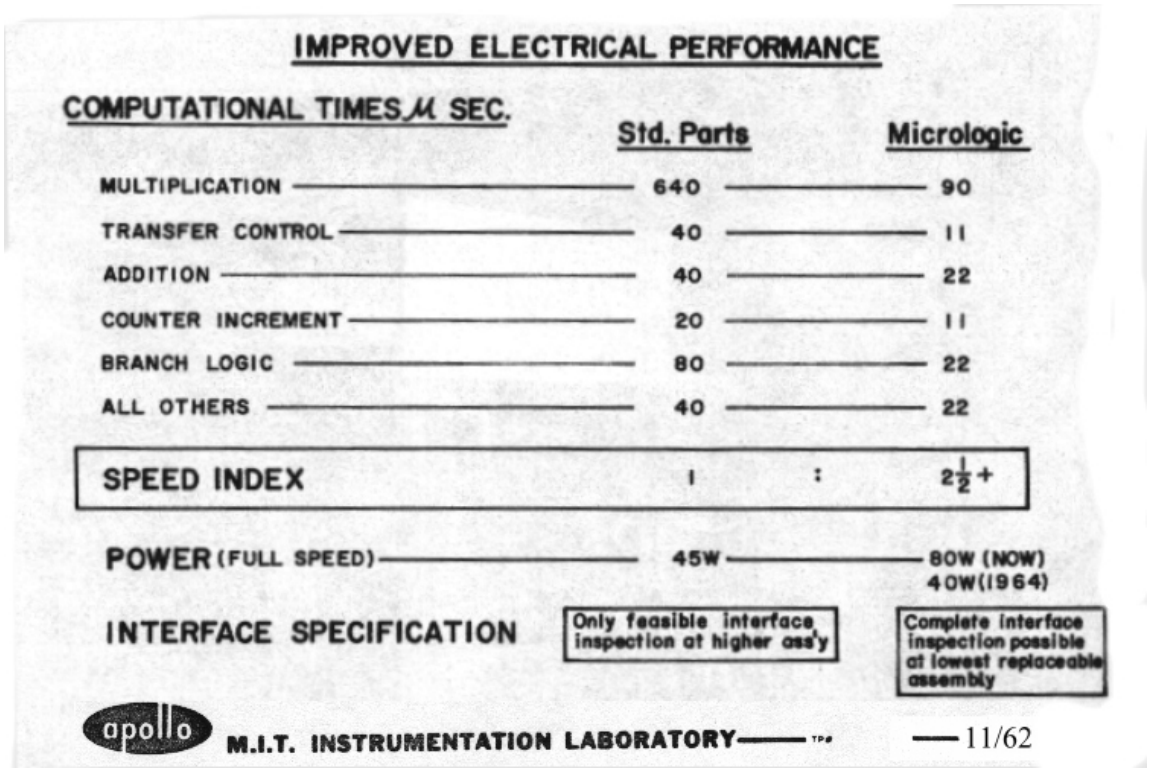
- Better thermal interface with Spacecraft (Connector)
- Permits Spacecraft coldplate integrity

SIMPLIFICATIONS

- Front vs. Top Replacement
- Flexible Cable Eliminated
- Tracks, Rails, & Extractor Tool Eliminated

COMPLEXITY COMPARISON CHART

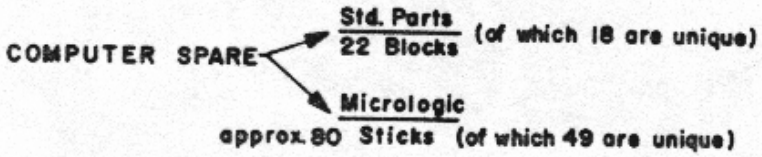




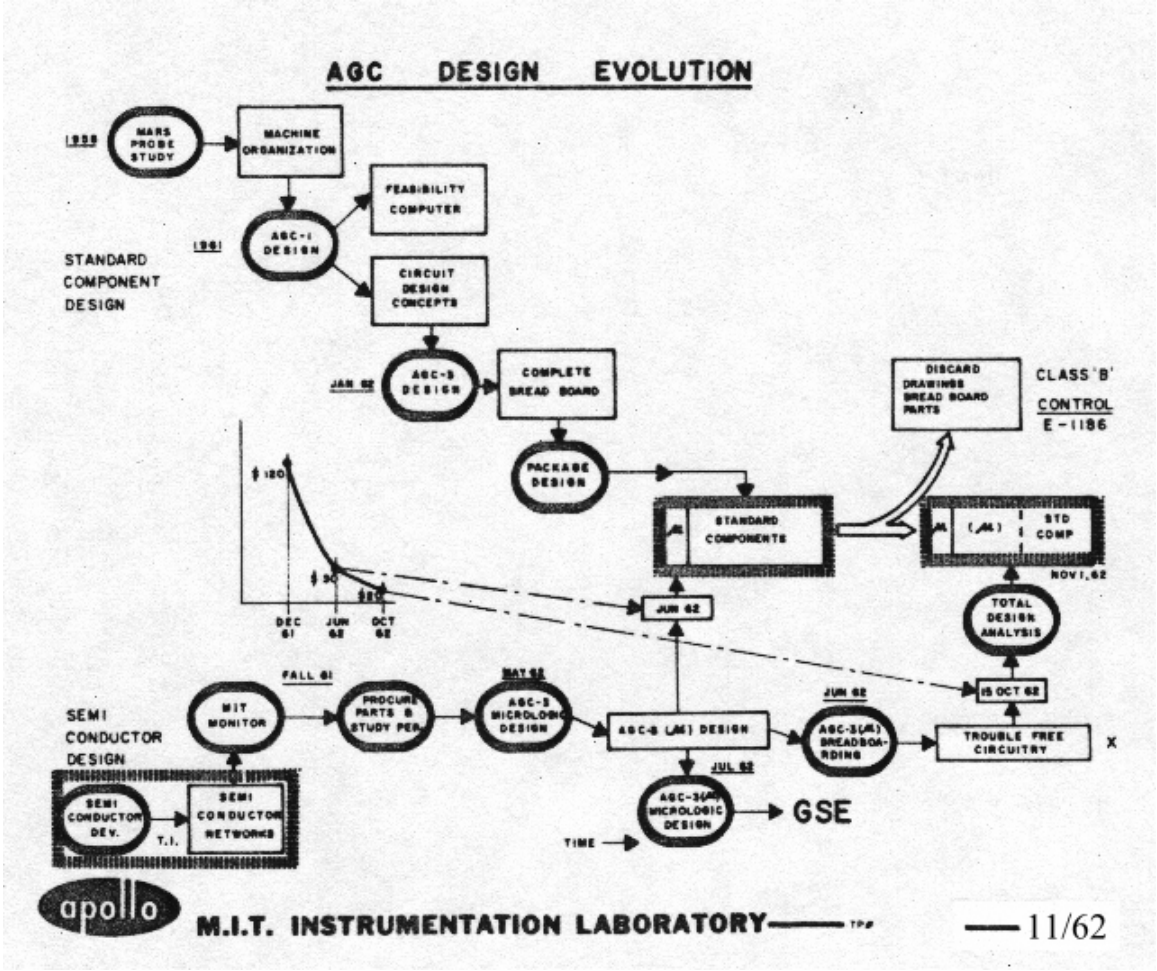
An increased computational capacity would be possible in a smaller volume and became necessary when the functional requirements of the Lunar Landing Module were developed during the NASA JSC sponsored Implementation Meetings in 1964.

SIMPLIFIED LOGISTICS

1. REDUCED COST OF UNIT SPARE
   Spare at lower assembly level. (stick not block)
   Throwaway of less expensive unit.
2. REPLACEMENT UNIT HAS MULTIPLE USE.
3. REDUCED COSTS OF SPARES INVENTORY



4. SIMPLIFIED TRAINING OF ASTRONAUT & FIELD SERVICE PERSONNEL
   (Simpler Spares Replacement)



The development plan presented in this slide explains how the redesign of the logic section of the AGC could be phased into the hardware design with minimum disruption to production schedules.

Following the presentation, a letter was sent from Dr. Draper to Mr. Frick formalizing the requested design change. NASA responded in Dec. 1962 with the approval. Copies of both letters are in the Appendix of "Journey To The Moon".

Opposition developed rapidly. A Raytheon engineer made a worst case analysis and proved that under worst case conditions Micrologic would not function. To prevent such an occurrence the logic gate needed to be carefully specified and logic design ground rules enforced.

Soon after NASA approval, reliability statisticians took over and proved mathematically that the computer's failure rate would be excessive. Then in early 1964, when the second generation, Block II, computer design introduced the dual Micrologic gate in a flat pack configuration, Bellcom engineers raised objections. Their objections were based on the sealing difficulty that the industry was experiencing with the flat pack. NASA JSC performed an independent investigation and found that most military programs were planning to use the flat pack and that the sealing difficulty was solvable. However, the reliability predictions continued to raise questions about the computer's potential to meet the requirements of lunar missions. It was not until computers in field service were operating for extended periods without failure that the questioning faded away.

Following is a sample of the memoranda and letters that relate to these reliability issues and the actions that NASA took. These are referenced in "Journey To The Moon".

See the AGC-LVDC Comparison Study and the set of Memos.

Eldon C Hall